ORIGINAL ARTICLE

Application of neuronavigation system in intracranial meningioma surgery: a retrospective analysis of 75 cases

Aplicación del sistema de neuronavegación en la cirugía del meningioma intracraneal: un análisis retrospectivo de 75 casos

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Abstract

Objective: *Neuronavigation is an extremely common and useful system in intracranial surgeries. It is used to determine the pre-operative incision, perform the most appropriate craniotomy, and provide intraoperative guidance. However, its use in meningioma surgery is controversial, and there is a dilemma whether it is necessary. This study was performed to determine the effect of neuronavigation in meningioma surgery.* **Materials and methods:** *Information related to pre-operative clinical evaluation and use of neuronavigation, neuroimaging, intraoperative tumor and surgical related information, and post-operative outcomes of 75 consecutive patients with meningiomas between January 2015 and 2020 were retrospectively collected. The values between groups were statistically compared.* **Results:** *There were no significant differences in pre-operative patient and tumor characteristics between the groups. In cases using neuronavigation, the mean operative time, craniotomy size, and blood loss during tumor resection were significantly lower, and post-operative hospital stay was shorter in these patients ($p < 0.05$). However, there were no differences in post-operative complications and clinical outcomes.* **Conclusion:** *The use of neuronavigation in meningioma surgery reduces blood loss during surgery, reduces the surgical time, and shortens the post-operative hospital stay. Thus, we conclude that the neuronavigation system is useful in meningioma surgery.*

Keywords: *Neuronavigation. Meningioma. Resection.*

Resumen

Objetivo: *La neuronavegación ha tomado su lugar como un sistema muy común y útil para cirugías intracraneales. Este estudio se realizó para revelar su efecto en la cirugía de meningioma.* **Materiales y métodos:** *Se recopiló retrospectivamente información relacionada con la evaluación clínica preoperatoria, neuroimagen, información relacionada con el tumor y la cirugía intraoperatoria y los resultados posoperatorios de 75 casos consecutivos con meningiomas entre enero de 2015 y 2020. Los valores entre grupos se compararon estadísticamente.* **Resultados:** *No hubo diferencias significativas en las características preoperatorias de los pacientes y las características del tumor entre los grupos. En los casos en los que se utilizó neuronavegación, el tiempo operatorio medio, el tamaño de la craneotomía y la pérdida de sangre durante la resección del tumor fueron significativamente menores, y la estancia hospitalaria postoperatoria fue más corta en estos pacientes ($p < 0.05$). Sin embargo, no hubo diferencia en las complicaciones postoperatorias y los resultados clínicos.* **Conclusión:** *El uso del sistema de neuronavegación en la cirugía del meningioma reduce la pérdida de sangre durante la cirugía, acorta el tiempo*

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quirúrgico y reduce la estancia hospitalaria postoperatoria. Creemos que el sistema de neuronavegación es útil en la cirugía del meningioma.

Palabras clave: *Neuronavegación. Meningioma. Resección.*

Introduction

Since the introduction of frame based stereotactic neurosurgery by Spiegel and Wycis four decades ago, the development of frameless stereotactic surgery with computer-assisted three-dimensional digitalization has revolutionized neurosurgery[1]. Frameless stereotaxy or neuronavigation allows pre-operative planning as well as intraoperative guidance, localization, and orientation.

Although the use of the neuronavigation system in intracranial glioma and metastasis surgery has been fully accepted, there is a dilemma whether it is necessary in intracranial meningioma surgery[2]. With the exception of small convexity meningiomas, locating the tumor is usually not a problem in meningioma surgery. The main difficulties are performing the most appropriate craniotomy and dural opening and preventing damage to the arterial and venous structures during surgery and deterioration of intraoperative orientation due to displacement of anatomical landmarks in large tumors[3]. The neuronavigation system stands as a good guide in solving these problems. A search of the English and Turkish literature revealed that the studies presenting the results on the use of the neuronavigation system in meningioma surgery are quite limited. Therefore, this study aimed to examine the effect of neuronavigation on surgical outcomes.

Materials and methods

We retrospectively evaluated 75 patients who underwent surgical resection of meningiomas with or without neuronavigation. This study received approval from the local ethics committee. Information on clinical history, surgical outcome, and pathological and radiological results of patients who underwent surgery for intracranial meningioma between 2015 and 2020 was obtained from their case files and electronic record cards.

The surgeries were performed by different surgeons using the same surgical technique as described in citation[4]; microneurosurgical tumor resection was performed under craniotomy. All procedures were performed by a team headed by a senior surgeon (HHK). Team members had a long-term cranial surgery experience before the initiation of the study. Neuronavigation was used in meningioma surgery after 2017 (Fig. 1). The senior surgeon had performed hundreds of meningioma surgeries before the start of the study, the first 20 cases in which navigation was used were not included in the study so that the difference in learning curve after the neuronavigation system was introduced did not affect the study results. An infrared-based navigation system (Brainlab Kick; Brainlab AG, Feldkirchen, Germany) was used intraoperatively. The following variables were saved: sex, age, symptoms at presentation, tumor location and size, craniotomy size, operative time, hospital stay, intraoperative blood loss, post-operative complications, and follow-up results. Karnofsky performance status was decided based on the archival records of pre-operative examinations and clinical evaluations.

Tumor size and location were determined based on pre-operative post-contrast magnetic resonance images, and tumor volume was calculated according to the widely used ABC/2 formula[5]. The extent of resection was assessed using the Simpson grading system[6]. Simpson grade I and II resections were considered gross total resection. The extent of resection was decided according to the discretion of the senior neurosurgeon during the surgery and/or the evaluation of the radiological images obtained within the first 48 h postoperatively. The World Health Organization grading system was used to classify the histology of meningiomas[7]. Deaths occurring within the 1st month after surgery and as a result of complications related to surgery were considered surgical mortality. Clinical follow-up results were decided according to the examination 12 months after surgery. The median follow-up duration was 24 months. Magnetic resonance imaging was performed 6 months after initial gross total resection of meningiomas to confirm tumor recurrence.

Statistical analysis

The analysis of this study was conducted using SPSS software, version 22.0 (IBM Corp., Armonk, NY). The distribution of variables was evaluated for normality using the Shapiro–Wilk test. For the evaluation of categorical data, χ^2 test was used if the number of observations was > 5, and Fisher's exact

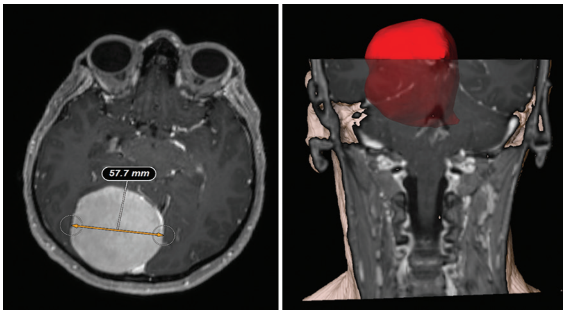


Figure 1. *Three-dimensional imaging of the tumor with neuronavigation during pre-surgical planning.*

Table 1. A: Patients' demographics. B: pre-operative clinical features and tumor characteristics

Variables	With navigation	Without navigation	p-value
A			
Total cases	43 (57.3%)	32 (42.7%)	0.62
Age	56.4 ± 11	58.5 ± 14	0.48
Gender			
Male	13	8	0.79
Female	30	24	0.40
B			
Variables	**With navigation**	**Without navigation**	**p-value**
Symptoms and signs			
Headache	38	27	0.61
Seizure	17	12	0.85
Vision[+] impairment	7	2	0.28
Gait disturbance	12	11	0.54
Confusion[+]	7	5	0.93
Weakness	18	19	0.81
Tumor location[+]			
Skull base	10	4	0.12
Convexity	23	16	0.32
Parasagittal	8	11	0.42
Other	2	1	0.21
Hounsfield Unit	51.2 ± 10.8	48.81 ± 7	0.52
Tumor size (ml)	37.94 ± 14.6	41.3 ± 13.29	0.31
KPS	83.02 ± 10.8	76.25 ± 16.8	0.52

[+]*Fisher exact test was used*

Chi-squared test was applied if it was < 5. Normally distributed data comprising continuous variables were analyzed using the Student t-test, and non-normally distributed data were compared using the Mann-Whitney U test. $p < 0.05$ was considered statistically significant.

Results

In our study, 43 patients (57.3%) underwent surgical intervention with neuronavigation (2017-2020) and 32 cases (42.7%) underwent surgery without neuronavigation (2015-2017). The mean age of patients in this study was 56 and 58 years in the with- and without-navigation groups, respectively. Before the surgery, there were no differences in terms of patients' demographics and tumor characteristics (Table 1A and B).

The mean operative time, craniotomy size, and blood loss during tumor resection were significantly lower in cases using neuronavigation. Thirty-nine patients (90.7%) underwent Simpson grade I and II resection with neuronavigation and 28 cases (87.3%) underwent grade I and II resection without neuronavigation. Simpson grade I and II resections were considered as gross total resection. There was no significant difference in the extent of tumor resection ($p = 0.62$). Furthermore, 72% of patients in the neuronavigation group and 75% of patients in the non-neuronavigation group had grade I meningioma. There was no significant difference between the groups in terms of histopathological results ($p = 0.92$) (Table 2).

In the post-operative follow-up, there was no difference in hematoma in the surgical cavity, cerebrospinal fluid leakage, surgery-related infections, and systemic complications between the two groups (Fig. 2). However, the average durations of hospital stay in patients were 13 ± 2 days and 18 ± 3 days in the with- and without-neuronavigation groups, respectively; thus, the hospital stay duration was significantly lower in the neuronavigation group ($p < 0.05$).

The clinical symptoms were significantly improved after tumor resection in both groups. However, with respect to the improvement of symptoms between the groups, there were no significant differences (Table 3).

Discussion

The application of neuronavigation systems in neurosurgical procedures provides the following information: performing minimal and optimal craniotomies, accurately localizing subcortical lesions, and defining lesion boundaries[8]. Pre-operative surgical planning using the guidance of appropriate technological developments will minimize the margin of error during surgery and reduce the risk of complications. The

Table 2. Comparison of intraoperative variables and post-operative pathological results

Parameters	With navigation	Without navigation	p-value
Surgery time (mean, minutes)	206	166	0.02*
Cranitomy size (mean, cm^2)	25.7	34.1	0.02*
Blood loss during surgery (mean, ml)	970	1810	0.01*
Simpson's grading⁺ (number of cases, percent)			
Grade I	3 (7%)	2 (6.2%)	0.61
Grade II	36 (83.7%)	26 (81.2%)	0.24
Grade III	3 (7%)	3 (9.3)	0.31
Grade IV	1 (2.3%)	1 (3.1%)	0.42
Histological grade⁺ (WHO grade) (number of cases, percent)			
Grade I	31 (72%)	24 (75%)	0.32
Grade II	11 (25.5%)	7 (21.5%)	0.23
Grade III	1 (2.5%)	1 (3.5%)	0.71

*Statistically significant.
⁺Fisher exact test was used.
cm^2: square centimeters; ml: milliliter.

Table 3. Comparison of follow-up results and clinical improvements

Variables	With navigation (n)	Without navigation (n)	p-value
Total cases	43 (57.3%)	32 (42.7%)	0.62
Symptoms and signs⁺			
Headache	19	20	0.61
Seizure	7	5	0.85
Vision impariement	3	1	0.18
Gait disturbance	6	4	0.54
Confusion	2	1	0.93
Weakness	9	7	0.81
30-day mortality	4	3	0.94
KPS (mean)	83.02 ± 10.8	76.25 ± 16.8	0.52

⁺Fisher exact test was used.
The symptoms and signs stated in the table were detected at the post-operative 12th month visit.

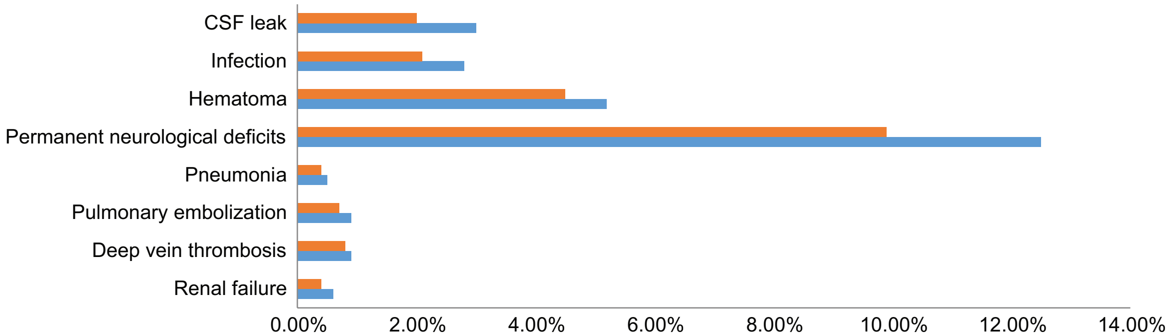
neuronavigation system is an important guide in this regard.

The most important goal of neurosurgeons is to perform tumor resection as wide as possible without harming the patient or with the least damage. Barnett reported that neuronavigation contributes to the surgical procedure itself by allowing smaller and better-centered craniotomies[9]. Our study also found that the craniotomy flap was smaller when navigation was used. Bir et al. reported that making the craniotomy flap the center of the pathology and observing neurovascular structure adjacent to the tumor with neuronavigation during surgery widened the resection margin, and this situation reduced the recurrence rate[1]. However, our study found that the extent of resection was similar in both groups. Meningiomas present as intracranial extra-axial lesions with dural attachment. We believe that meningiomas have a sharp border with the normal parenchyma tissue, and after reaching the meningioma, if there are no features that will prevent tumor resection, gross total resection can be performed. Lemée et al. reported that skull-base location and bone invasion were associated with the poor resection of meningiomas[10].

Paleologos et al. reported that the operative time, amount of intraoperative blood loss, and length of hospital stay after surgery were significantly lower when neuronavigation was used[11]. We also observed that blood loss was lower by approximately 800 mL and the operative time and hospital stay were shorter in the neuronavigation group. Lower intraoperative blood loss is possibly associated with smaller craniotomies and avoidance of major vascular structures. In a meningioma surgery, intraoperative blood loss is mostly caused by the bone flap; therefore, smaller craniotomies reduce blood loss. Planning the most suitable entrance for the lesion and performing small craniotomies reduces the surgical time and blood loss, eliminates the need for brain traction, and prevents brain contusion[12].

The patients' post-operative outcomes were quite satisfactory in many modern series. Mortality rates of convexity and parasagittal meningiomas were almost 0% and exceeded 8% for tumors in the sphenoid wing and 12% for those in the petroclival region[13]. In our study, we found that the post-operative mortality and morbidity rates were consistent with the reported levels, and there was no significant difference in post-operative follow-up results between the two groups.

A biggest problem that can arise, especially in a developing country like ours, where there is scarcity of resources, is the cost of equipment and the cost-benefit ratio. The use of neuronavigation allows safe surgery in which more tumors can be excised intraoperatively, the results of our study and the literature show that it shortens the surgical time and reduces the length of hospital stay. However, the high capital expenditure, absence of intraoperative imaging, and lack of trained dedicated supporting technical staff does make the neuronavigation a strain on the resources. Our study was a retrospective observational study and focused more on surgical outcomes



	Renal failure	Deep vein thrombosis	Pulmonary embolization	Pneumonia	Permanent neurological deficits	Hematoma	Infection	CSF leak
With navigation	0.40%	0.80%	0.70%	0.40%	9.90%	4.50%	2.10%	2.00%
Without navigation	0.60%	0.90%	0.90%	0.50%	12.50%	5.20%	2.80%	3.00%

With navigation Without navigation

Figure 2. *There was no difference between the two groups in terms of post-operative complications.*

of the navigation system; therefore, a larger randomized trial with more objective criteria would be necessary to provide definitive answers.

Limitation

The patient series was relatively small and the follow-up results were short-term. It would be more appropriate to evaluate the results of long-term follow-up with a larger number of patients.

Conclusion

Neuronavigation technology provides an important advantage for modern surgical approaches. The results of studies with relatively few cases show that operative time and hospital stay are shortened and blood loss during surgery is reduced; however, there were no differences in terms of post-operative complications and follow-up results with the use of this technology in meningioma surgery. Future studies with larger series, especially randomized comparisons conducted with an objective view, are required to compare the true effectiveness and enhance the accuracy of navigation systems in surgical resection of intracranial meningiomas.

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Conflicts of interest

The authors declare no conflicts of interest.

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data. The authors declare that no patient data appear in this article.

Right to privacy and informed consent. The authors have obtained approval from the Ethics Committee for analysis and publication of routinely acquired clinical data and informed consent was not required for this retrospective observational study. We obtained local ethic committe approvel from Ataturk University, School of Medicine.

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